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EVAPOTRANSPIRATION TOOLBOX FOR THE UPPER RIO GRANDE WATER OPERATIONS MODEL

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1. INTRODUCTION

The Bureau of Reclamation (Reclamation) and others have determined a need for rapid improvement in measuring and predicting daily riparian and crop water use in the Rio Grande Basin. Reclamation is developing an Evapotranspiration Toolbox (ET Toolbox) for estimating these daily water use requirements at a resolution useful for implementation in the Upper Rio Grande Water Operations Model (URGWOM). The URGWOM is a multi-agency effort to develop a numerical computer surface water model that will cover the Rio Grande from Colorado to Fort Quitman, Texas. The primary purpose of this model will be a daily water operations accounting tool that can be used for basin-wide water management and planning.

The goal of the ET Toolbox project is to develop a methodology for automatically inputting daily riparian and crop water use estimates, open water evaporation estimates, and rainfall estimates to the URGWOM. The initial development work focused on the Middle Rio Grande area from Cochiti Dam to San Marcial, which is just south of the Bosque del Apache National Wildlife Refuge in New Mexico. ET including riparian vegetation, irrigated crops, and open water evaporation accounts for about 60 percent of the water depletions over this reach of the Rio Grande.

2.UPPER RIO GRANDE WATER OPERATIONS MODEL

Water resources in the Upper Rio Grande Basin are in ever-increasing demand for such diverse uses as irrigation, municipal, industrial, endangered species, and recreation. To provide for these water uses, water managers, such as Federal agencies, State agencies, and municipalities, need improved tools. The URGWOM is one of these tools. URGWOM is a collaboration via a Memorandum of Understanding between Reclamation, U.S. Army Corps of Engineers (COE), U.S. Fish and Wildlife Service, U.S. Geological Survey (USGS), the U.S. section of the International Boundary and Water Commission, and the U.S. Bureau of Indian Affairs. Assistance is provided by the New Mexico Interstate Stream Commission, City of Albuquerque, Middle Rio Grande Conservancy District (MRGCD), Los Alamos National Labs, and others.

Ultimately, the Rio Grande Basin rivers and reservoirs from the Colorado / New Mexico border to Fort Quitman, Texas will be incorporated into the model studies, including eight reservoirs. Five are Reclamation reservoirs: Heron, El Vado, Nambe Falls, Elephant Butte, and Caballo. Three are COE reservoirs: Abiquiu, Cochiti, and Jemez Canyon. The purpose of the model is to modernize and enhance coordinated water operations, accounting, and planning for uses including annual operating plans and the Upper Rio Grande Water Operations Review for the basin Environmental Impact Statement. Expected benefits from the model include:

- Utilizing a completely linked computer model of this portion of the Rio Grande system to provide daily data for use in multi-agency water operations, accounting, forecasting, and planning.
- Predicting daily flows, storages, and other information throughout the system for environmental, municipal, industrial, and recreational studies.
- Large electronic data collection assembled and available for use by others.

Accomplishments include completion of a test case model of the Rio Chama, with reservoirs, reaches, and operational rules. The Rio Chama is a small but representative reach of the Upper Rio Grande Basin and a tributary of the Rio Grande. It was chosen because of the availability of data and the complexity of the river system. The Rio Chama has most of the physical components such as diversions, river reaches, confluences, and hydropower that are encountered downstream in the remainder of the Upper Rio Grande. Currently, modeling of the Rio Grande from the Colorado state line to Cochiti Lake is underway, with partial completion of modeling to Elephant Butte Reservoir. Challenges of the model include data deficiencies, particularly from Cochiti to Elephant Butte, that limit attainable accuracy in modeling, and litigation activities below Elephant Butte that prevent modeling anything but flood control operations.

3. RIVERWARE©

The URGWOM multi-agency steering committee chose Riverware as the river basin modeling system to be used by the URGWOM. Riverware contains water accounting and ownership tools and peripheral water budget and flood routing tools that are being configured for the URGWOM. Riverware is a generic reservoir and river system modeling tool that uses an object-oriented design and a graphical user interface (GUI) that allows users to develop data-driven variable time-step models for both planning and operational uses. Being of flexible and extensive design, Riverware can be readily customized to fit specialized modeling needs for any river-system network (developed by the user with the GUI) with different controllers or solution techniques. Riverware was initially developed in 1993 and is now the

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result of a continuing effort between the Center for Advanced Decision Support for Water and Environmental Systems (CADWES) at the University of Colorado, Reclamation, and the Tennessee Valley Authority.

4. ET TOOLBOX

The ET Toolbox is an extension of Reclamation's Agricultural WAter Resources Decision Support (AWARDS) system that provides Internet access to high resolution rainfall and daily crop water use estimates for improving the efficiency of water management and irrigation scheduling (Brower and Hartzell, 1998). The ET Toolbox computer is a Sun Ultra 60 workstation operating with the Sun Solaris UNIX system and located at Reclamation's Technical Service Center office in Denver, Colorado. This computer automatically acquires all of the necessary hourly and daily data, and also provides Internet and File Transfer Protocol (FTP) service for the resulting products. The ET Toolbox uses the National Weather Service (NWS) Stage III multi-sensor (radar and gage) hourly precipitation estimates at a continuous spatial coverage of the Hydrologic Rainfall Analysis Project's (HRAP) 4 km x 4 km grid resolution. These Stage III rainfall estimates offset a portion of ET surface water depletion estimates.

The primary purpose of the ET Toolbox is to estimate daily rainfall and water depletions along the Rio Grande for each HRAP grid cell and the specified river reaches. These daily ET estimates and summary year-to-date cumulative ET estimates are available to users and water managers via the Internet. The daily cumulative river reach ET estimates will be provided to the URGWOM by Riverware, using a Data Storage System (DSS) developed by the COE Hydrologic Engineering Center.

The ET Toolbox integrates the Stage III rainfall estimates with weather data from automated stations, Geographic Information System (GIS) mapping, remote sensing vegetation imagery, communication technology, and ET based on the Modified-Penman methodology, to estimate daily water requirements for each HRAP grid cell in the vicinity of the Rio Grande. Eight different GIS vegetation data sets that cover portions of the Middle Rio Grande area were evaluated, the most recent being aerial photography taken during a June 1999 ET field study. All of the vegetation data sets are transposed to the HRAP grid cell resolution and compared to determine changes in the vegetation and water depletion over time.

Figure 1 is an example of the Rio Grande Basin ET Toolbox Project area, available from Reclamation's NEXRAD Web page at http://www.usbr.gov/rsmg/nexrad. The area from Alcalde, New Mexico to the northern boundary of the Bosque del Apache National Wildlife Refuge is shown. The color shaded 24-hr NEXRAD STAGE III rainfall estimates are shown in inches for August 10, 1999, Mountain Daylight Time as received from the NWS West Gulf River Forecast Center (WGRFC). The white sub-window boxes are generally designed to include the agricultural areas between Rio Grande diversion dams that provide water to users within the MRGCD. Clicking within these white sub-window boxes allows the user to further pop-up detailed ET charts for each crop grown in the area, as detailed in the AWARDS system (ref. Paper 5.3 in this Preprint). The small white boxes to the left of the sub-window boxes allow the user to pop-up the more detailed features of the ET Toolbox as shown in Figure 2. The white triangles link to the USGS Internet site offering near real-time streamflow and river stage information. Most of the features of the images in Figures 1 and 2 were imported from various GIS coverages. The red lines in Figure 2 are the MRGCD water distribution system. These maps are produced for the Internet site using the National Center for Atmospheric Research (NCAR) Graphics product.

4.1 Weather Data

A requirement for computing evapotranspiration for the ET Toolbox is acquisition of appropriate daily weather data, which includes maximum and minimum temperatures, dew point temperature or relative humidity, solar radiation, wind speed, and rain gage measurements. These data are accessed by the ET Toolbox computer via FTP automated processes to computer systems at the New Mexico Climate Center at the New Mexico State University (NMSU) and the MRGCD. The University gathers the 24-hr data from the state weather station network using a telephone communication system to the weather stations. The MRGCD implemented a radio transmission system to 10 project weather stations. The MRGCD procedure downloads the data every hour and generates daily summaries. The NWS Weather Forecast Office in Albuquerque imports the hourly rainfall data from the project weather stations into the Advanced Weather Interactive Processing System (AWIPS), thereby making hourly rain gage observations available to the WGRFC for fine tuning the Stage III rainfall estimates. Figure 3 is an example listing of the daily weather data available for Internet access by clicking on the + signs in Figure 2.

4.2 Evapotranspiration (ET)

Researchers at the NMSU chose a modified version of the Penman equation for calculating reference evapotranspiration (Eto). This value is empirically derived from experimental data based on a grass referenced method that combines energy balance and heat and mass transfer functions (ASCE, 1990). A crop coefficient (Kc) is applied to the Eto to determine the daily ET, in inches, as applied in the ET Toolbox, using the formula:

$$ET = Kc \times Eto$$

The crop coefficient Kc is based on the ratio of an estimated ET, as measured by lysimeter in the field, to Eto, as calculated from the modified Penman equation from Cuenca (1982). Crop coefficients are normally derived in conditions where crop growth is not limited by physiological factors, available moisture, disease, or

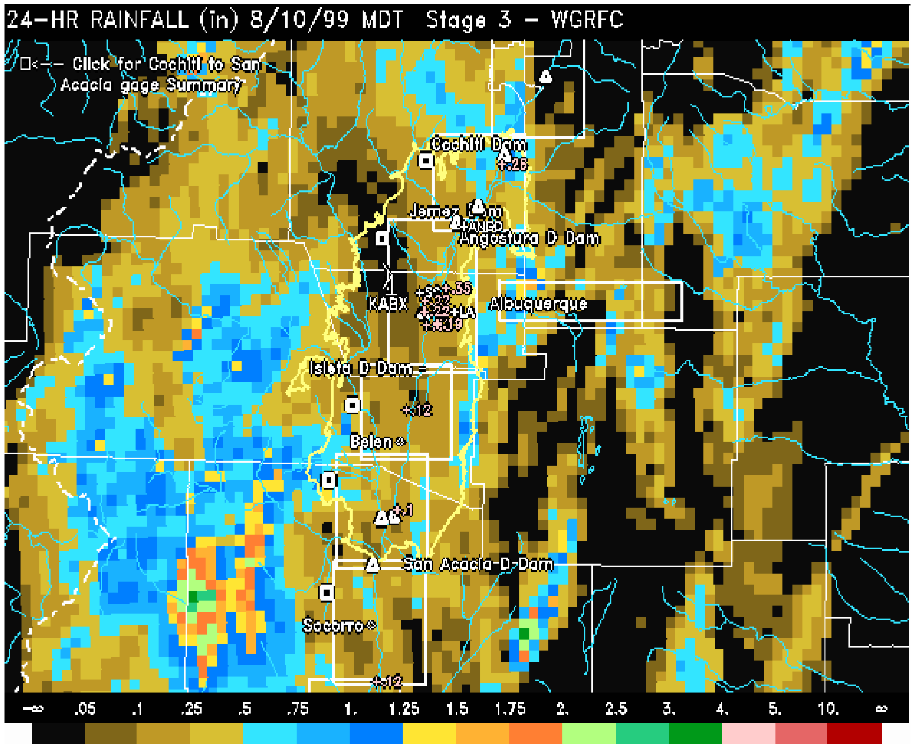

Figure 1. Example of an interactive image showing the 24-hr NEXRAD STAGE III rainfall estimates.

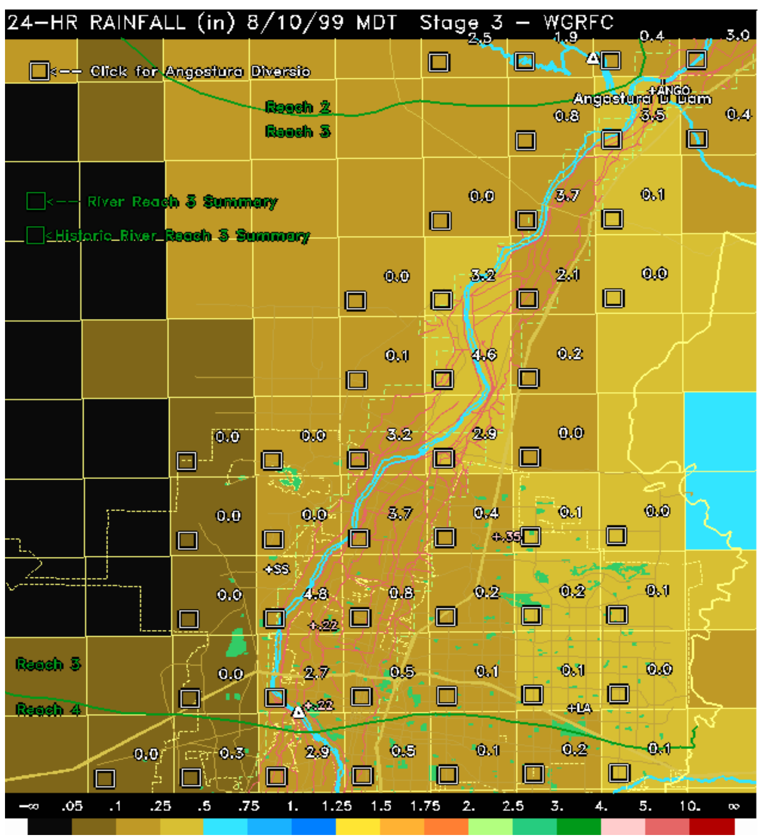

Figure 2. Example of an interactive image showing the grid cell 24-hr ET estimates and color shaded 24-hr STAGE III rainfall estimates.

Albuquerque, NM - Rio Grande Nursery Station - Weather Data - 1999

	Aug. 4	Aug. 5	Aug. 6	Aug. 7	Aug. 8	Aug. 9	Aug. 10
Max. Temp. (F)	81.0	81.0	84.0	91.0	92.0	88.0	81.0
Min. Temp. (F)	62.0	63.0	62.0	60.0	60.0	65.0	61.0
Avg. Wind (Mi/Hr)	0.7	1.1	0.6	0.6	0.9	0.8	0.9
Rel. Hum. (%)	39.0	32.5	36.5	29.5	26.0	22.5	28.5
Rain (In)	0.86	0.42	0.00	0.00	0.00	0.00	0.22
Solar Rad. (Mj/Sq m)	14.00	0.30	20.00	25.20	22.50	19.50	14.20

Gage Monthly Total Rain:	
January	0.12
February	0.00
March	1.39
April	0.48
May	0.29
June	0.22
July	1.55
August	2.97

Figure 3. An example interactive listing of weather station data for the past seven days and the monthly rain gage totals.

other factors that might hinder plant growth. Graphs of crop coefficients can be presented as a function of time, seasonal growth stages, percent of effective cover from zero to 100, or Growing Degree Days (GDD). Sammis (1985) states that since the plant development depends on the heat units, a physiological clock can be developed based on GDD. Crop coefficients as a function of GDD developed under a particular climate condition can easily be transferred to areas with a different climate.

GDDs are accumulated heat that will contribute to plant growth and development from the period of planting until harvesting, or bud break to defoliation. The average method was chosen in New Mexico (King, 1998) for determination of GDD using:

GDD = ((Daily Maximum Temperature + Daily Minimum Temperature) / 2) - Base Temperature

where the maximum and/or minimum temperatures are replaced with cutoff temperatures when limits are exceeded. Negative GDD values are prevented.

4.3 Land Use Classifications

An important component of the ET Toolbox is determination of the vegetative growth acreage of agricultural crops, riparian vegetation, and open water in each of the 4 km x 4 km HRAP grid cells. These data are then applied to the empirically derived ET to produce a daily volumetric water requirement for each HRAP cell. For the 1999 season, the Middle Rio Grande Land Use Trend Analysis Geographic Information System Data Base (1997) for 1992/93 was chosen, since it was the most current analysis performed within the upper reaches of the river system from Cochiti Dam to San Acacia Dam. The purpose of the Land Use Trend Analysis (LUTA) was to identify and quantify land use trends in the Albuquerque basin, New Mexico, over the last 58 years on those lands that significantly impact groundwater resources. Historic and current aerial photography and 1992 Landsat Thematic Mapper satellite imagery were used as primary sources for compiling the LUTA GIS database. The yellow outline shown in Figure 1 represents the Landsat image that includes the LUTA. Reclamation and the City of Albuquerque identified four periods of time for the LUTA: 1935, 1954/55, mid 1970s, and 1992/93. A GIS database was constructed for each of the four time periods.

Coverages from the GIS were transformed to the HRAP 4 km x 4 km grid cells using GIS tools provided by members of the Civil, Agricultural, and Geological Engineering Department at NMSU. Results, which were first separated into four counties, were merged and placed into files acceptable to the ET Toolbox computer program. Approximately 127 HRAP grid cells from the LUTA were included in the 1999 ET Toolbox for the agricultural and riparian areas along the Rio Grande from Cochiti Dam to San Acacia Dam. A Reclamation GIS coverage study completed in 1998 was used to get the riparian growth classification between San Acaicia Dam and the northern border of the Bosque del Apache National Wildlife Refuge. This added 21 HRAP grid cells to the study, although there were no agricultural coverages available for this area.

4.4 ET Toolbox Calculations and Results

Computer processes were developed to collect all of the required data sets and calculate the daily consumptive use (DCU) in acre-feet for each crop using:

$$DCU = Eto\ (in) \times Kc \times Acres\ /\ 12\ (in/ft)$$

where Eto is the reference evapotranspiration in inches, Kc is the crop coefficient, and Acres is the crop acreage of the grid cell.

All of the crop and riparian (including open water) acre-feet values (DCU's) are summed to arrive at an estimated consumptive use for each cell. These cell values are printed to a pop-up interactive image on the Internet site as shown in Figure 2. By clicking on the printed value within the cell, a pop-up ET Toolbox Cell Detail table will appear, as shown in Figure 4. The figure shows the consumptive use for each agricultural crop, riparian vegetation and open water for the past 10 days (August 1 through August 10, 1999), and totaled for agricultural and riparian vegetation. The NEXRAD rainfall estimate is subtracted from the consumptive use to arrive at the URGWOM water use. On some rain days such as August 5, 1999, the rainfall exceeded the consumptive use. In this case the excessive moisture became surface runoff, was stored in the soil profile, or deep percolated into the groundwater environment.

The user can pop-up a cell summary by clicking on the individual cell boxes shown in Figure 2. The example ET Toolbox Cell Summary in Figure 5 shows daily consumptive use values in Cubic Feet per Second (CFS) for both agricultural crops and riparian vegetation for the periods January 1-2 and August 7-10, 1999. The daily URGWOM water use in CFS is the total CFS reduced by the NEXRAD rainfall estimate. A summation to-date for the year in acre-feet is also presented. Water managers can use this information to become more aware of the yearly water use on each cell of approximately 4,000 acres of land. In this example, there are a total of 23 vegetation classifications from the LUTA, although only 13 of them (as shown in Figure 4) consumed project water. The remaining classifications such as desert shrub or vacant land are not considered. For reporting purposes, open water evaporation is considered a riparian usage.

The user can pop-up a river reach summary by clicking on the green boxes shown in Figure 2. An example ET Toolbox Reach Summary is in Figure 6. This example displays data similar to the Cell Summary, but contains all of the grid cells within a river reach. River reaches are defined as areas of the river basin between the USGS streamflow gaging stations.

These reach values are also posted daily to a file for use by the DSS for import into Riverware. Riverware will use these data for performing a water depletion budget for the Rio Grande.

Historic reach summaries from 1985 through 1998 are also being processed for URGWOM and posted on the Internet site. These provide a measurement of daily water use over a period of years and show the effect of changing agricultural practices, urbanization, and riparian corridor vegetation changes.

In addition to the cell and river reach summaries, diversion summaries with similar content are available by clicking on the boxes near the top left corner of either Figures 1 and 2. A summary for all diversions from Cochiti Dam to the San Acacia USGS gaging station is provided from Figure 1, and an example diversion summary, from Angostura Dam, is provided from Figure 2. These diversion summaries are used by Reclamation and district water operations staff to better manage daily water releases from the reservoirs while satisfying downstream water use requirements for agricultural crops, riparian vegetation, and open water evaporation.

5. FUTURE IMPROVEMENTS

The ET Toolbox was under development in 1999 with the paper illustrating the current status as of October 1, 1999. There are plans to improve and expand the system in 2000 and future years. The requirements of URGWOM will dictate how and where this system is used. It is anticipated that expansion into the headwaters of the Rio Grande into Colorado and expansion south of San Acacia Dam to Fort Quitman, TX, will occur. Improved and more recent land use GIS data, such as the 1999 aerial photography at ½ meter resolution from Cochiti Dam to Elephant Butte Reservoir, will be incorporated. Modified crop coefficients for riparian growth based on recent research in the Bosque del Apache National Wildlife Refuge will improve the results of the system. Further studies of open water evaporation, which is a significant water usage element in the Rio Grande Basin, will also improve water use estimations. Improved ET forecasting for the next 24 hours will be achieved by obtaining high resolution model forecast parameters from the NWS.

6. SUMMARY

- The ET Toolbox system demonstrates a methodology that integrates NEXRAD STAGE III rainfall estimates, weather station data, crop and riparian ET requirements, GIS information, and land usage with modern computer, communication, and Internet technologies for improved water resources management.
- Daily crop water use estimates for improving water management of the Rio Grande Basin are easily available for the specific crops and riparian growth in each 4 km x 4 km HRAP grid cell area.
- Near real-time water use data are available for the Upper Rio Grande Water Operations Model via the Riverware basin modeling system.
- Water operations staff have a tool for better managing reservoir water diversions to satisfy water use requirements.

ET TOOLBOX CELL DETAIL

Greater Albuquerque

Vegetation classification: LUTA 1992/93

Cell number: 104x306

Weather station: Albuquerque, NM - Rio Grande Nursery Station

Last 10 Day's URGWOM Water Use in Acre-Feet (CFS)

Consumptive Use

Crop	Acres	Aug. 1 (1999)	Aug. 2	Aug. 3	Aug. 4	Aug. 5	Aug. 6	Aug. 7	Aug. 8	Aug. 9	Aug. 10
Alfalfa	292.9	6.3	5.9	3.9	4.4	6.6	6.1	8.1	7.3	6.3	4.6
PastGrass	28.8	6.2	5.7	3.5	4.4	6.2	6.2	7.9	7.1	6.2	4.4
Urban Irr	92.3	1.1	1.0	0.6	0.8	1.1	1.1	1.4	1.2	1.1	0.8
Park/Golf	8.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Rip. Wood	13.6	0.2	0.2	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.1
Rip. Shrub	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Open Water	153.2	1.9	1.8	1.1	1.4	1.9	1.9	2.4	2.2	1.9	1.4
Misc Grass	66.9	0.9	0.8	0.6	0.6	0.9	0.9	1.1	1.1	0.9	0.7
Tree Fruit	5.6	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Nursery St	26.5	0.3	0.3	0.2	0.2	0.3	0.3	0.4	0.4	0.3	0.2
Misc Fruit	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Misc Vegs	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bosque	184.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Totals	1376.5	17.1	15.9	10.2	12.1	17.4	16.9	21.8	19.6	17.1	12.4
		(8.6)	(8.0)	(5.1)	(6.1)	(8.8)	(8.5)	(11.0)	(9.9)	(8.6)	(6.3)
Agricul.	855.4	13.0	12.0	7.7	9.1	13.2	12.7	16.5	14.9	13.0	9.4
		(6.5)	(6.1)	(3.9)	(4.6)	(6.7)	(6.4)	(8.3)	(7.5)	(6.5)	(4.7)
Riparian	353.7	2.1	2.0	1.3	1.5	2.1	2.1	2.7	2.4	2.1	1.5
		(1.1)	(1.0)	(0.6)	(0.8)	(1.1)	(1.1)	(1.4)	(1.2)	(1.1)	(0.8)
NEXRAD											
Rainfall Est.		0.0	72.5	33.8	102.3	66.6	0.0	0.0	0.0	0.0	12.9
		(0.0)	(36.6)	(17.1)	(51.7)	(33.6)	(0.0)	(0.0)	(0.0)	(0.0)	(6.5)
URGWOM											
Water Use		17.1	-56.6	-23.6	-90.2	-49.2	16.9	21.8	19.6	17.1	-0.5
		(8.6)	(-28.6)	(-11.9)	(-45.6)	(-24.8)	(8.5)	(11.0)	(9.9)	(8.6)	(-0.2)

Figure 4. An example ET Toolbox Cell Detail water use table that includes consumptive use, NEXRAD rainfall, and URGWOM water use for the past 10 days.

ET TOOLBOX CELL SUMMARY
Window named: Greater Albuquerque
Cell number: 104x306
Vegetation classification: LUTA 1992/93
Weather station: Albuquerque, NM - Rio Grande Nursery Station
Up to 23 vegetation classifications representing 3985.30 acres
(Daily URGWOM Water Use = Daily Consumptive Use Total - Rain)

1999 Month Day	Daily Consumptive Use Total CFS	Agriculture CFS	Riparian CFS	Daily URGWOM Water Use CFS	Total URGWOM Water Use To-Date Since Jan. 1, 1999 AC-FT
Jan. 1	1.2	0.6	0.6	1.2	1.2
Jan. 2	0.8	0.4	0.4	0.8	2.0
|	|	|	|	|	|
Aug. 7	11.0	8.3	1.4	11.0	1082.7
Aug. 8	9.9	7.5	1.2	9.9	1092.6
Aug. 9	8.6	6.5	1.1	8.6	1101.3
Aug. 10	6.3	4.7	0.8	-0.2	1101.0

Agriculture acreage = 855.4
Riparian acreage = 353.7 (Includes Bosque and Open Water)

Figure 5. An example ET Toolbox Cell Summary showing daily consumptive use values for agricultural crops and riparian vegetation, and a summation to-date showing the effect of NEXRAD rainfall estimates.

ET TOOLBOX REACH SUMMARY
Summary for the Reach Named: URGWOM Reach 3 (San Felipe to Cent. Ave. gage)
Vegetation classification: LUTA 1992/93
Up to 25 vegetation classifications representing 135600.38 acres
(Daily URGWOM Water Use = Daily Consumptive Use Total - Rain)

1999 Month Day	Daily Consumptive Use Total CFS	Agriculture CFS	Riparian CFS	Daily URGWOM Water Use CFS	Total URGWOM Water Use To-Date Since Jan. 1, 1999 AC-FT
Jan. 1	14.5	6.2	8.3	14.5	28.7
Jan. 2	9.6	4.4	5.2	9.6	47.8
|	|	|	|	|	|
Aug. 7	115.0	73.7	19.7	115.0	21711.7
Aug. 8	103.6	66.6	17.6	101.6	21912.8
Aug. 9	90.5	58.0	15.6	90.5	22092.0
Aug. 10	65.6	42.1	11.4	-37.8	22017.1

Agriculture acreage = 7084.5
Riparian acreage = 8388.2 (Includes Bosque and Open Water)

Figure 6. An example ET Toolbox Reach Summary showing daily consumptive use values for agricultural crops and riparian vegetation, and a summation to-date showing the effect of NEXRAD rainfall estimates.

REFERENCES

American Society of Civil Engineers, 1990: Manual 70, Evapotranspiration and Irrigation Water Requirements.

Brower, L.A., and C.L. Hartzell, 1998: Agricultural Water Resources Decision Support System (AWARDS). *Proceedings, 14th Technical Conference - 1998, U.S. Committee on Irrigation and Drainage*, pp 127-140.

Cuenca, R.H. and M.T. Nicholson 1982: Application of Penman Equation Wind Function. *J. Irrig. Drain. Div.. ASCE 108(IR1),* pp. 13-24.

King, P.K. and S. Bawazir, 1998: Evapotranspiration Crop Coefficients as a function of Heat Units for Some Agricultural Crops in New Mexico. *New Mexico Water Resources Institute*.

Middle Rio Grande Land Use Trend Analysis GIS Data Base, 1997: *Middle Rio Grande Water Assessment Supporting document Number 13*. Bureau of Reclamation, Albuquerque, NM.

Sammis, T.W. et al., 1985: Evapotranspiration Crop Coefficients Predicted Using Growing Degree Days. *ASCE 28(3)*, pp. 773-780.

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